Remote monitoring and “Tele-orthodontics”: Concept, scope and applications

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Tele-orthodontics is a broad term that encompasses remote provision of orthodontic care, advice, or treatment via information technology. The purposes of the article were two-fold: (1) to review the rather new concept, applications and scope of teleorthodontics, and (2) to present preliminary results of a study with and without Dental Monitoring™ (DM) usage on appointment efficiency, patient perspectives and patient demographics. The sample was comprised of 74 consecutively treated Invisalign® patients using DM™ and 85 consecutively completed Invisalign® patients. An online questionnaire was given to the DM™ group to assess the patients’ perspective on the ease of use and benefit to treatment experience using a 5-point Likert scale. Also requested was a list of 5 benefits and problems while using DM™. Independent t-tests were used to determine any inter-group differences in, number of appointments and age; a chi-square test was used for differences between genders. Significance was set at \( P \leq 0.05 \). Mean number of appointments was significantly lower by 1.68 appointments for DM compared to control (\( P < 0.001 \)). Age averaged 3.2 years younger for the DM group (\( P < 0.05 \)). More males used DM than the control group (31.6% vs 16.7%, \( P < 0.05 \), respectively). The mean Likert scale rating for “ease of use” was 4.31 out of 5.0, while benefit to treatment experience rating was 4.4. The most oft-mentioned perceived benefits were “better communication” (47 times), “increased convenience” (44 times), “reduced number of appointments” (40 times), and “ease of use” (38 times). The most oft-mentioned problems were related to the “difficulty of taking scans” (27 times) and “reduced communication” (12 times). Preliminary study results suggest the number of appointments may be reduced with Dental Monitoring. In addition, there was a positive patient perception on the use of DM. (Semin Orthod 2018; 24:470–481) © 2018 Elsevier Inc. All rights reserved.

Introduction

Tele-orthodontics is a broad term that encompasses remote provision of orthodontic care, advice, or treatment through the medium of information technology, rather than direct personal contact. A simple and relevant example is an orthodontist seeking advice from colleagues by sharing digital records and communicating over the Internet. Less commonly, tele-orthodontic consults and treatments have been reported in conjunction with general dentists in order to facilitate orthodontic treatment.12 In the early to mid-2000s, promising results were achieved by orthodontists supervising general dental practitioners in real time to provide orthodontic services to patients with limited access to orthodontic care.13 Simple remote monitoring of patients during the retention period has also been performed with patients sending pictures...
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increased efficiency.

An important premise for the development of the prescription appliances, customized appliance systems and clear aligner therapy (CAT), has been reduced chair-side time and lesser in-office visits. Efficiency is an important “buzzword” in orthodontic practice management lexicons. One of the pitfalls of traditional orthodontics is the treating of patients based on estimates of a patient’s response to treatment. Generally, patients are required to have in-office visits (or aligner changes) at preset intervals, which are average time frames applied to all patients and not necessarily the ideal time-frame specific to the individual patient and treatment requirements. With the advent of tele-orthodontics, and more specifically remote monitoring, the scheduling of in-office visits can be personalized per patient, creating a supposedly more efficient workflow. This not only maximizes profitability by reducing chair time, but also improves patient convenience.

An important “application” (app) that facilitates this technology is Dental Monitoring™ (DM), which allows patients to accurately capture their occlusion using a smart phone. Since people are increasingly using smart phones and “apps” on them, orthodontic applications on these platforms have also correspondingly increased. Scans made by a patient using a smart phone (photos or videos) are analyzed by DM and viewed by the orthodontist who is then able to provide real-time monitoring of the patient’s treatment remotely. This could be especially important in areas with limited access to orthodontic care. Similarly, those who travel frequently or have busy schedules can benefit tremendously from remote monitoring. Other perceived advantages include earlier diagnoses, closer management through remote monitoring, savings in time and transportation costs and increased convenience for patients. Remote patient monitoring may also reduce overall treatment time via early interception of problems such as non-tracking aligners, debonded brackets or broken appliances, allowing for such problems to be addressed promptly.

Tele-orthodontics may be used for all appliances, ranging from phase-1 devices to traditional appliances to CAT, but may be more appropriate in customized appliances that require less frequent in-office adjustments. The convenience of reduced appointments may however be replaced by the inconvenience of submitting weekly scans, which can become frustrating or tedious as the scans sent may be rejected and require retaking. In addition, there may be a loss of rapport with the orthodontist due to the diminished contact time. Prior consent and training is necessary for the patient before the start of treatment to ensure better understanding and cooperation.

**How Dental Monitoring™ works?**

DM™ is a software-based program that allows practitioners to remotely monitor patients’ treatment progress. It consists of three integrated platforms: a mobile app for the patient, a patented movement tracking algorithm and a web-based Doctor Dashboard where updates of the patients’ progress are received (Fig. 1).

**Mobile app:** The DM™ app is currently available for Android and iOS operating systems. The app guides the patient through the process of taking the pictures with the dedicated cheek retractor on a schedule suggested by DM™ and refined by the doctor according to the treatment needs (Fig. 2). The app allows the patient to review their past photos, observe their treatment progress, practice in the demo mode, and receive notifications from their doctor.

**Patented movement tracking algorithm:** Initially, the 3D model of a patient’s dentition is uploaded to the Doctor Dashboard. This 3D model serves as the initial reference point for tooth position. When the patient submits their photo exams, the pictures are uploaded to the servers and verified to ensure suitable quality to be processed by the DM™ algorithm. Thereafter, the algorithm is able to calculate individual tooth movements in all planes of space (Fig. 3). There is a claimed precision of less than 0.1 mm of movement and less than 0.5° for tip and torque.

**Online Doctor Dashboard:** The Doctor Dashboard is completely web-based and does not require additional software. After the analysis by the algorithm is complete, the results are checked by a team of DM™ doctors and are then presented on the web-based Dashboard in the form of graphs, photos and a 3D visualization of current tooth position (called 3D Matching).
The orthodontist is notified immediately when new results are available, or if any alerts or objectives have been detected, and can then communicate with the patient through the app. The clinician can set parameters to receive alerts in circumstances that require attention, such as non-tracking aligners, broken appliances or oral hygiene problems. Similarly, notifications can be set for specific objectives such as 2 mm overjet or class I canines (Fig. 4).

Figure 1. Dental Monitoring consists of three integrated platforms: a mobile application for the patient, a patented movement tracking algorithm, and a web-based Doctor Dashboard.

Figure 2. Use of the Dental Monitoring mobile app, in addition to the calibrated cheek retractor, to take pictures.
Figure 3. Visualization of individual tooth movements in all planes of space, with a claimed accuracy of 0.1 mm linearly, and 0.5° of tip and torque.

Figure 4. Alerts and notifications on the Doctor Dashboard.
The activity graph helps to evaluate the activity of treatment or post-treatment stability (Fig. 5). It allows the doctor to identify exactly how much the teeth have moved since the last photo exam. This can help determine when an archwire or an aligner needs to be changed allowing for customized treatment based on the patient’s individual biological response. 3D Matching allows the doctor to visualize and replay tooth movement as an updated 3D model of the teeth is created with every photo exam taken by the patient. All photos taken by the patient with the DM™ application and the dedicated cheek retractor are available on the Dashboard. Clinicians can easily compare them with similar photos at different dates to visualize changes.

DM™ now provides four tiers of monitoring, varying in their uses and monthly costs, as follows:

**Pre-treatment monitoring:** Allows for an unlimited duration and can be used while waiting for tooth eruption or while using a phase-I device. The default frequency of photo exams is one photo every two months but is modifiable upon request.

**Treatment monitoring:** Allows for unlimited treatment duration and can monitor all types of treatment including conventional, customized vestibular or lingual appliances and CAT. The default frequency of photo exams, modifiable upon request, is once a week for aligners and one every two weeks for the other treatment types. Treatment monitoring includes post treatment monitoring for two years.

**Post treatment monitoring:** Allows for 2-years to monitor post treatment stability. The default frequency of photo exams changes with time i.e. a photo every week for the first month, one photo per month for the next 6 months and then one photo every 2 months for the remainder of post treatment monitoring.

**DM GoLive™:** DM GoLive™ is a patented algorithm supervised by the DM™ clinical team that detects non-tracking aligners.14 As opposed to fixed aligner changes, the patient receives a weekly “GO” or “NO-GO” notification from the DM™ app indicating whether they should move to the next aligner or remain in the current one. The doctor is informed whenever a “NO-GO” notification is sent, identifying the individual teeth that are not tracking as well as other undesirable situations such as poor oral hygiene; the doctor can override NO-GO at any stage. It should be noted that DM GoLive™ does not track individual tooth movement for 3D matching as do the other options.

**Patient perception of DM - a pilot study**

Preliminary data obtained from a private practice in the Gold Coast, Australia, has provided some
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insight into Dental Monitoring GoLive™ and its clinical applications. Claims of the company indicate shorter treatment times, reduced number of appointments, reduced number of refinements and increased communication. Unfortunately, there is currently no evidence-based data on the use of DM™ or remote monitoring in general. Hence, the objective of this preliminary pilot study was to investigate the efficacy of DM™ and remote monitoring by determining if DM GoLive™ reduces the number of appointments required compared to a control. Secondary objectives were to compare the demographics between the two groups and to assess the patients’ perspectives on using DM™ during treatment. The null hypotheses were as follows: There is no difference in the number of appointments nor demographics between the DM™ group and the control. The study was carried out independently by the authors without any financial assistance or funding from a third party that can constitute a conflict of interest.

The sample from a private practice in the Gold Coast, Australia, comprised of 79 consecutively treated patients using DM™ in conjunction with Invisalign® (experimental DM™ group) and 94 consecutively completed patients using only Invisalign® (control group). Patients were given the option of utilizing DM™ after being informed about its pros and cons and were treated at no additional cost if they chose to use the app. After exclusions due to inadequate records, partial fixed appliances and auxiliary appliances, five patients were excluded in the DM™ group (n = 74) and nine patients in the control group (n = 85), resulting in a total sample size of 159 subjects.

Since DM™ is a recent application, only three patients had completed treatment in the experimental group, (mean treatment time was 200.2 ± 75.2 days) at the time of evaluation. In order to match the groups, we capped the control group to the initial 210 days (approximately 7 months) of treatment, i.e. a mean of 208.3 ± 7.9 days. An independent student t-test showed no significant difference between the two groups (P = 0.36). An online questionnaire was then given only to the DM™ group to assess the patients’ perspective on the ease of use and perceived benefit to treatment on a 5-point Likert scale. They were also requested to list five benefits and five problems experienced while using DM™. The questions were open ended to avoid the bias of preselected options. 70 patients (94.6%) responded to the questionnaire.

Independent t-tests were used to determine any inter-group differences in number of appointments and age; a chi-square test was used for differences between genders. Significance was set at P ≤ 0.05.

Mean numbers of appointments were significantly lower by 1.68 (P < 0.001) for DM™ (3.07 ± 1.8) compared to the control (4.75 ± 1.6) over the evaluated treatment period. Age averaged 3.2 years younger for the DM™ group (24.5 ± 11.8) than the control (27.7 ± 10.5, P < 0.05). Moreover, gender distribution was significantly different (P < 0.05) with the DM™ group comprising of 31.6% male and 68.4% female while the control group comprised of 16.7% male and 83.3% female (Table 1).

Questionnaire results showed that 86% responded use of the DM™ app was “easy” or “very easy” to use, 7% regarded ease of DM™ use as “moderate”, while 7% also regarded the DM™ app as “difficult” or “very difficult” to use. The mean Likert scale rating was 4.31 out of 5.0 (Fig. 6); 84% indicated that DM™ was “beneficial” or “very beneficial” to their treatment experience with a mean rating of 4.4, 10% indicated DM™ was of moderate benefit to their treatment, while 6% indicated that it was not beneficial (Fig. 7). The most oft-mentioned benefit perceived by patients using DM™ was “better

Table 1. Results of independent t-tests comparing Dental Monitoring (DM) and control groups of Invisalign® patients for age, gender distribution, treatment length and number of appointments. P signif. represents probability significance; n represents sample size; M:F represents male-to-female ratio.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Age (in years)</th>
<th>Genders (M:F)</th>
<th>Treatment length</th>
<th>No. of appointments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>79</td>
<td>24.5 ± 11.2</td>
<td>25:54</td>
<td>200.2 ± 75.2</td>
<td>3.06 ± 1.8</td>
</tr>
<tr>
<td>Control</td>
<td>84</td>
<td>27.7 ± 10.5</td>
<td>14:70</td>
<td>208.3 ± 7.9</td>
<td>4.75 ± 1.6</td>
</tr>
<tr>
<td>P signif.</td>
<td></td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
<td>P &gt; 0.05</td>
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communication” (mentioned 47 times) followed by “increased convenience” (44 times), “reduced number of appointments” (40 times) and “ease of use” (mentioned 38 times) (Fig. 8). The most oft-mentioned problem identified by DM™ patients was related to the “difficulty of taking scans” with 27 mentions; the others being “none” (16 times) and “reduced communication” (12 times) (Fig. 9).

If were to critically analyze these responses, there was a reduction in mean number of appointments (1.68) for the DMTM group compared to control after approximately 7 months of treatment, a reduction of approximately 35%. Extrapolation of these findings to an overall treatment time scale of 24 months would suggest a reduction of 5.8 appointments for DMTM usage. Clearly, a study with completed patients in

![Graph showing ease of use of DM app to use](image)

**Figure 6.** Questionnaire results of when asked to rate the ease of use of DM on a 5-point Likert scale. The mean rating was 4.31.

![Graph showing benefit of DM on treatment experience](image)

**Figure 7.** Questionnaire results of when asked to rate the benefit of DM on treatment experience on a 5-point Likert scale. The mean rating was 4.4.
both groups would be needed in order to verify this projection. In addition, an assessment of treatment outcomes would be needed in order compare the efficacy between the two therapies.

In this study, patients were given the choice to use DMTM at no additional cost, reducing confounding factors. There was a significant difference in the ages of the DM™ (24.5 ± 11.8) and

**Figure 8.** Questionnaire results of an open-ended question when asked to rank 5 benefits of using DM.

**Figure 9.** Questionnaire results of an open-ended question when asked to rank 5 problems using DM.
control (27.7 ± 10.5, P < 0.05) groups. While the DMTM group was younger than the control by 3.2 years, this difference was likely not clinically important but nevertheless hints at the trend for younger patients being more inclined toward using DMTM and being more comfortable with new technology. The gender distribution was also significantly different (P < 0.05) with the DMTM group comprising of 31.6% male and 68.4% female, and the control group comprising of only 16.7% male and 83.3% female. This result was interesting and suggested that males were more likely to use DMTM than females. Perhaps males were more enthusiastic about reducing the number of in-office visits and preferred the greater convenience that DMTM offered in contrast with direct communication with the orthodontist. However, these results should be interpreted with caution as the patients were from a single practice and may not represent the demographics in other areas around the world.

The questionnaire results suggest patients adapt well to DMTM usage; 86% of DMTM users responded that the app was “easy” or “very easy” to use with a mean rating of 4.31. While DMTM app was easy to use for a majority of patients in the present study, this finding is not consistent with 3.0 and 3.3-star app ratings on the Apple App Store (5 reviews) and Google Play Store (48 reviews), respectively. The majority of DMTM users (84%) responded that DMTM was “beneficial” or “very beneficial” to their treatment experience with a mean rating of 4.4. The implication being that DMTM met their expectations of reducing in-office visits and increasing convenience. Again, this finding is not consistent with 3.0 and 3.3-star app ratings on the App Store (5 reviews) and Play Store (48 reviews), respectively.

The most frequently mentioned benefits perceived by patients using DMTM were “better communication” (mentioned 47 times), “increased convenience” (44 mentions) and “reduced number of appointments” (40 mentions). Better communication via the app was achieved with prompt, same day responses from the DMTM team or the orthodontist after scans were sent. Whilst “increased convenience” and “reduced number of appointments” could have been grouped together, most patients indicated these benefits separately and were hence grouped as such. Increased convenience included responses such as: “can be performed at home”, “do not need to take off from work” and “can be done while on holiday”. An unexpected benefit of DMTM was the patient’s ability to see their treatment progress (21 mentions). The app allows the patient to view their previous scans, encouraging and motivating them by showing their progress since treatment began. The problem identified by patients most frequently was “difficulty of taking scans” with 27 mentions; this finding is in agreement with reviews on the Play Store. The most commonly reported problems on the Play Store were related to software problems and problems and difficulties in taking scans. In the present study, 12 mentions were made of “reduced communication”, which was surprising as “better communication” was mentioned 47 times as a benefit of DMTM. This contradiction could be due to software problems and/or their expectation of what communication entails and how much the patient expects from DMTM and the orthodontist. Surprisingly, one patient mentioned he preferred to see the orthodontist rather than use the app. This low number may be because all patients were given the option of using DMTM prior to treatment and those who preferred in-office visits, likely decided to not use DMTM.

Under the conditions of the present preliminary study, the null hypotheses were rejected and the conclusions reached were as follows:

- The DMTM group had reduced number of appointments (3.07) compared with the control group (4.75), with a difference of 1.68 appointments after 7 months of evaluation.
- Extrapolation of this finding over the course of an average 24-month treatment period would result in 5.8 fewer appointments for a DMTM sample- however this should be interpreted with caution.
- The DMTM group was significantly younger than the control group, with ages of 24.5 and 27.7 years, respectively.
- The DMTM group had almost double the percentage of males (31.6%) than the control group (16.7%).
- DMTM users indicated the app was easy to use with 86% of the sample indicating it was “easy” or “very easy” with a mean rating of 4.31 out of 5.0.
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- DM™ was perceived as beneficial to the treatment experience of the patients with 84% indicating that DM™ was “beneficial” or “very beneficial” with a mean rating of 4.4 out of 5.0.
- The most frequently mentioned benefits perceived by patients using DM™ were “better communication” (mentioned 47 times), “increased convenience” (44 mentions) and “reduced number of appointments” (40 mentions).
- The most common problem perceived by patients using DM™ was related to the “difficulty of taking scans” with 27 mentions.

While the preliminary results suggest that number of appointments may be reduced with Dental Monitoring™, further studies should be performed to evaluate overall active treatment time, treatment outcomes and refinement differences in order to judge efficacy of DM™ usage.

Future implications

With the exponential incorporation of technology, the practice of orthodontics has considerably changed. The goal of tele-orthodontics is to reduce patient’s office visits while maintaining regular monitoring, without compromising results. Moreover, tele-orthodontics may be useful for remote consultations, which could be performed across the world without the patient potentially stepping into the office. Comprehensive patient records would still require in-office visits; however, it does open new channels for orthodontic consultations and second opinions.

Technological advances come with a dark side as well. Reducing the number of face-to-face appointments diminishes the rapport between doctor and patient. This traditional relationship may be reduced or lost, and with that, possibly trust as well. The doctor—patient relationship has traditionally been much more than transactional. Dunbar reported in a pilot study that 70% of subjects felt that the face-to-face aspect of the consultation was extremely important and the majority preferred this over the exclusive use of tele-orthodontic technology. New legal issues will also play a role with patient confidentiality potentially being at risk due to records being communicated over the internet. Patient complaints of malpractice may also increase if patients do not receive an acceptable level of care or if practitioners do not maintain the level of healthcare expected.

Tele-orthodontics has already gained some notoriety in the USA by converting “patients” into “consumers” due to the “direct-to-consumer” approach from several companies; a trend that may, regretfully, be expected to continue in the future. These companies offer clear aligner treatment at a much cheaper rate than orthodontists and market directly to the “consumer”. Kelleher, a prosthodontist, has aptly described this phenomenon as the “Uberization of orthodontics”. This new trend has come as a result of prospective patients looking for cheaper and aesthetic alternatives to traditional orthodontics, and service providers reducing care to a “commodity”. A qualified dentist or orthodontist handles each case remotely, however no records other than casts/intra oral scans are made. The extent of communication between the “consumer” and the “treating” doctor is also in question, which is especially problematic if treatment goes awry or outcomes are deemed unacceptable.

The opinion piece of Ackerman and Burris has been sufficiently rebutted numerous times after it was published, and although it was not the intention of this article to respond, it must be expanded upon as the current state of affairs of tele-orthodontics. According to Ackerman and Burris, the future of orthodontics is going the way of the airline industry, i.e. patients simply wish to go “from point A to B” and will skimp on the “experience”, basing the decision to obtain orthodontic treatment primarily on cost and convenience. Although this opinion piece continues the disturbing trend of renaming patients as consumers, they make a point that the new generation of patients may indeed have different priorities and expectations. However, the airline industry example cannot simply be extrapolated to the healthcare sector. The end result of orthodontics is not so definite as the destination of an airplane, and the orthodontist is not a travel agent. Furthermore, the potential for causing harm becomes a serious sequela if the patient is not diagnosed or treated appropriately. Access to care cannot be held up as a slogan, whilst at the same time placing patients at risk of harm. Unfortunately, companies whose primary aim is profit, do not hold themselves to the ethical principle of
non-maleficence, embodied by the phrase “primum non nocere” (first, do no harm). It is mind-boggling that over 30 years after an orthodontist was found guilty for causing a temporomandibular joint disorder (TMD), the same legal system is allowing poorly supervised orthodontic treatment. Wertheimer suggests that orthodontists themselves are somewhat to blame for this situation, citing lack of the pursuit for excellent treatment. Wertheimer,27 however, this would continue the march to mediocrity and sub-par treatment.

The orthodontic community at this point has an inherent distrust in tele-orthodontics and its potential to not only reduce their patient base, but also cause harm to patients. However, outside the USA where regulations of healthcare services have different protocols, orthodontists may be more enthusiastic about the potential of tele-orthodontics. The key to the future of tele-orthodontics would be in balancing the benefits of in-office visits and direct patient-doctor relationships with the convenience and reduced costs of remote monitoring, on an individual patient-to-patient basis, while maintaining an excellent standard of care.

References


15. Likert R. A technique for the measurement of attitudes. 1932.


21. Ackerman M, Burris B. The way it was, the way it ought to be, the way it is, and the way it will be. Am J Orthod Dentofac Orthop. 2018;153(2):165–166. http://dx.doi.org/10.1016/j.ajodo.2017.09.010.


